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SPECIFICATION

VEHICLE IMPACT ATTENUATOR

5   TECHNICAL FIELD

The present invention relates to a vehicle impact attenuator to be installed on or in the vicinity of roads where vehicle collisions are liable to occur, in order to immediately stop a colliding vehicle and mitigate

10   the impact applied to the vehicle.

BACKGROUND ART

Vehicle impact attenuators are installed in places where vehicle collisions tend to occur, such as the

15   ends of median strips, road forks, and the ends of branch points for tollgates, in order to immediately stop a colliding vehicle and mitigate the impact applied to the vehicle, thereby preventing secondary accidents and reducing damage to the vehicle and its occupants.

20   Guard fences, such as steel guardrails or guard cables, can be described as vehicle impact attenuators. However, with these devices, colliding vehicles still receive a large impact, and the damage to the occupants and vehicles cannot be effectively inhibited. Further,

25   these devices are likely to greatly damage the colliding

vehicles and the scattered fragments are liable to cause secondary accidents.

Other vehicle impact attenuators include water-filled container-type impact attenuators. However, this type of devices also pose a problem in that a vehicle receives a large impact when it collides with them while traveling at a high speed. Further, containers knocked over by a vehicle may scatter on the road, or a colliding vehicle may not be decelerated even after knocking down the containers and may jump over the base of the containers into the opposite lane, causing secondary accidents.

In view of such problems, the present inventors conducted extensive research and proposed vehicle impact attenuators that comprise a shock absorber and a support fixed on the ground so as to support the shock absorber, wherein the support is released from the ground and made slidably movable when a load exceeding a set value is applied by a vehicle collision (Japanese Unexamined Patent Publication No. 2001-159107, hereinafter "Publication 1", and Japanese Unexamined Patent Publication No. 2003-64629, hereinafter "Publication 2"). The proposed devices make it possible to effectively absorb the impact, immediately stop the vehicle, and prevent the vehicle from receiving an impact load exceeding a set value.

However, since vehicle impact attenuators are generally installed in narrow places with limited space, such as the ends of median strips, the devices must be miniaturized or improved in impact load absorbing capacity

5   per installation space, so as to allow a smooth traffic flow and make the devices installable in more places. Moreover, the installation cost of vehicle impact attenuators must be reduced in order to make the devices installable in many places.

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DISCLOSURE OF THE INVENTION

A first object of the present invention is to provide a vehicle impact attenuator that can be installed in a narrow place with limited space, immediately stop a

15   colliding vehicle, and effectively mitigate the impact received by the vehicle. A second object of the present invention is to provide a vehicle impact attenuator that can be installed at low cost.

To achieve the above objects, a first vehicle

20   impact attenuator of the present invention comprises:

a shock absorber that deforms upon a collision of a vehicle to thereby reduce the impact on the vehicle;

a support for the shock absorber;

a holding portion that holds the support in a

25   vertical position in an installation area;

the support or holding portion having a release portion
that fractures upon application of a load equal to or
exceeding a set value to thereby release the support from
being held in a vertical position in the installation area,

5   and the support being plastically deformable by a load
lower than the set value.

A second vehicle impact attenuator of the
present invention is characterized in that the support in
the first vehicle impact attenuator is a pipe-like member;

10   the holding portion comprises a connecting portion fixed
on a lower part of the support, and anchor bolts that are
implanted in the installation area to thereby hold the
connecting portion in the installation area and that
function as the release portion; and the anchor bolts

15   fracture upon application of a load equal to or exceeding
the set value.

A third vehicle impact attenuator of the
present invention is characterized in that the holding
portion in the first vehicle impact attenuator comprises a

20   burying hole formed in the installation area to
accommodate a lower part of the support; the support is a
pipe-like or rod-like member and has cuts that are
positioned above the installation area when the support is
accommodated in the burying hole; and the cuts serve as

25   fracture starting points when a load equal to or exceeding

the set value is applied, and function as the release portion.

A fourth vehicle impact attenuator of the present invention is characterized in that the support in the third vehicle impact attenuator is a pipe-like member, and the plastic deformation occurs as flattening of the pipe-like member.

A fifth vehicle impact attenuator of the present invention is characterized in that a coil that is plastically deforms upon application of a load equal to or exceeding a predetermined value is further provided to the first vehicle impact attenuator; the holding portion has a burying hole formed in the installation area to accommodate a lower part of the support; the support is a pipe-like member and plastically deforms upon application of a load lower than the set value; the ends of the coil are disposed above and below the release portion and attached to an upper part of the support, which is released by the vehicle collision, and to the holding portion or a lower part of the support, which remains held after the vehicle collision.

A sixth vehicle impact attenuator of the present invention is characterized in that the coil in the fifth vehicle impact attenuator has a helical shape having a plurality of turns each of which is an approximate circle

with a coil diameter of not less than 110 mm and not more than 130 mm, a wire diameter of not less than 30 mm and not more 40 mm, and a number of turns of not less than 3 and not more than 20, and is made of structural steel.

5   A seventh vehicle impact attenuator of the present invention is characterized in that the support in the first vehicle impact attenuator is comprised of a plurality of the supports that are held adjacent to each other in the installation area, and the shock absorber is

10   supported by all of the supports.

An eighth vehicle impact attenuator of the present invention is characterized in that the holding portion in any one of the third, fourth or fifth vehicle impact attenuators is accommodated in the burying hole and

15   comprises a fitting member that engages and holds a lower part of the support, the fitting member has strength sufficient to approximately retain its original shape after the fracture of the release portion.

A ninth vehicle impact attenuator of the present

20   invention is characterized in that the set value at which the release portion fractures in any one of the second, fourth or fifth vehicle impact attenuators, is not less than 50 kN and not more than 900 kN, and the yield point load that causes the flattening as the plastic deformation

25   of the support is not less than 25 kN and not more than

800 kN.

A tenth vehicle impact attenuator of the present invention is characterized in that, the pipe-like member in the ninth vehicle impact attenuator is formed using iron or plastic, has an outer diameter of not less than 100 mm and not more than 800 mm, and a wall thickness of not less than 0.8 mm and not more than 100 mm.

An eleventh vehicle impact attenuator of the present invention is characterized in that the pipe-like member in any of the second, fourth or fifth vehicle impact attenuators contains an internal cushioning material.

In the first vehicle impact attenuator, at the time of a vehicle collision, the impact is first absorbed by the deformation of the shock absorber, then by the plastic deformation of the support, and then by the fracture of the release portion. When the load equals to or exceeds the set value, the release portion breaks to release the support, so that the impact on the vehicle can be limited to a predetermined value. Thus, the vehicle impact attenuator absorbs impact by plastic deformation of the support in addition to the buffering actions of the shock absorber and release portion. Accordingly, the attenuator has an impact load absorbing capacity that is higher than that achieved by the flexibility of the shock

absorber, due to the contribution of the plastic deformation of the support. Since the support does not increase the volume of the vehicle impact attenuator, the attenuator has a higher impact load absorbing capacity per

5   installation area than known vehicle impact attenuators. Therefore, the vehicle impact attenuator of the present invention is installable in a narrow space with limited space, effectively mitigates the impact received by a colliding vehicle, and immediately stop the vehicle. In

10   particular, when two or more vehicle impact attenuators are installed side by side so that, on release of the support of one attenuator, the colliding vehicle impacts with the subsequent attenuator, the use of the first vehicle impact attenuators can decrease the number of

15   attenuators that need to be installed, thereby greatly reducing the necessary installation space.

In the second vehicle impact attenuator, the use of anchor bolts that break upon application of a load equal to or exceeding a set value easily realizes a

20   release portion that releases the support.

In the third vehicle impact attenuator, the support and holding portion are integrally formed as one pipe-like member, and the cuts formed on the support and serving as a release portion simplify the structure of the

25   release portion, thereby reducing the production cost.

Further, the support can be erected and fixed simply by inserting a lower part of the support in a burying hole provided in the installation area, making the installation operation easy and the installation cost low. Furthermore,

5   the above structure enables installation in a narrow space. Moreover, the yield point load of the release portion can be varied with the shape of the cuts and therefore the breaking strength can be easily set at an optimum value, and thus a vehicle impact attenuator can be easily

10   provided which has a release portion with a breaking strength suitable for the conditions of the installation site.

In the fourth vehicle impact attenuator, a pipe-like member is used as the support. Thus, to mitigate the

15   impact by plastic deformation, the support is dented in the direction of the collision and then flattened by expansion of the dent in a direction approximately perpendicular to the direction of the collision. The flattening, in combination with the bending in the

20   vertical direction, flexibly absorb the impact in the direction of the collision. Moreover, since the flattening does not depend on the direction of the collision, the buffering action is stabilized. Furthermore, a general-purpose pipe-like member can be

25   used, lowering the production cost.

In the fifth and sixth vehicle impact attenuators, the coil continuously absorbs the impact even after an upper part of the support has been separated by a vehicle collision.

5   The seventh vehicle impact attenuator comprises a plurality of supports, and thus the plastic deformation of the supports greatly contributes to increase the impact load absorbing capacity. Further, such a structure dissipates the load received by a colliding vehicle.

10   In the eighth vehicle impact attenuator, even when a load equal to or exceeding the set value is applied at the time of vehicle collision, the impact is concentrated in the region with cuts, which has lower strength than the fitting member. The region with cuts

15 can be smoothly broken, thereby effectively inhibiting damage to the fitting member. Accordingly, after a vehicle collision, the vehicle impact attenuator can be easily withdrawn since the base for installation of the attenuator can be recovered by simply removing the remains

20 inside and around the fitting member. Moreover, the fitting member is reusable and simplifies the installation of a new vehicle impact attenuator. This reduces restoration cost as well as installation cost, and also decreases the necessary work time.

25   In the ninth vehicle impact attenuator, the set

value and yield point load are adjusted to a value in the prescribed range, whereby the effects described above are remarkably exhibited.

In the tenth vehicle impact attenuator, the yield point load of the pipe-like member can be adjusted to a value in the prescribed range.

The eleventh vehicle impact attenuator comprises an internal cushioning material that contributes to impact absorption when the pipe-like member is flattened. The impact absorbing capacity of the pipe-like member can be easily optimized by appropriately selecting the presence or absence of the internal cushioning material, and the form or quality of the internal cushioning material. Thus, a vehicle impact attenuator with an impact absorbing capacity suitable for the conditions of the installation site can be easily provided.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view illustrating a vehicle impact attenuator according to a first embodiment of the present invention.

Fig. 2 is a series of longitudinal sectional views illustrating the deformation of the vehicle impact attenuator illustrated in Fig. 1 at the time of a vehicle collision.

Fig. 3 is a perspective view illustrating a vehicle impact attenuator according to a second embodiment of the present invention.

Fig. 4 is a series of longitudinal sectional
5   views illustrating the deformation of the vehicle impact attenuator illustrated in Fig. 3 at the time of a vehicle collision.

Fig. 5 is a perspective view illustrating a vehicle impact attenuator according to a third embodiment
10 of the present invention.

Fig. 6 is a series of longitudinal sectional views illustrating the deformation of the vehicle impact attenuator illustrated in Fig. 5 at the time of a vehicle collision.

15   Fig. 7 is a series of cross sectional views illustrating example of the support.

Fig. 8 shows drawings of a part of the support. (a) to (c) are perspective views illustrating regions with cuts, and (d) is a longitudinal sectional view of a region
20 with a notch.

Fig. 9 is a pair of longitudinal sectional views illustrating examples of the fitting member.

Fig. 10 is a plan view illustrating an example of an arrangement of a plurality of vehicle impact
25 attenuators according to the first embodiment of the

present invention.

Fig. 11 shows a perspective view (a) and plan
view (b) illustrating a vehicle impact attenuator
according to the third embodiment of the present invention

5   installed behind an end portion of a guardrail supported
by a plurality of poles.

Fig. 12 is a perspective view illustrating a
vehicle impact attenuator according to a fourth embodiment
of the present invention.

10   Fig. 13 is a plan view illustrating an example
of an arrangement of a plurality of the vehicle impact
attenuator illustrated in Fig. 12.

Fig. 14 shows graphs schematically showing the
relation between the displacement and load of a pressure-

15   applying end pressed against the pipe-like member. (a)
shows the relation in the case where the pipe-like member
contains no internal cushioning material, and (b) shows
the relation in the case where the pipe-like member
contains an internal cushioning material.

20   Fig. 15 is a perspective view illustrating a
vehicle impact attenuator according to a fifth embodiment
of the present invention.

Fig. 16 is a series of longitudinal sectional
views illustrating the deformation of the vehicle impact

25   attenuator illustrated in Fig. 15 at the time of a vehicle

collision.

Fig. 17 is a graph schematically showing the relation between the displacement and load of a pressure-applying end pressed against the vehicle impact attenuator

5 illustrated in Fig. 15.

Fig. 18 shows graphs indicating measurement results on the coil used in the vehicle impact attenuator illustrated in Fig. 15 to absorb the load of a collision.

10 BEST MODE FOR CARRYING OUT THE INVENTION

Embodiments of the present invention are described below, referring to the accompanying drawings. (First embodiment)

Fig. 1 is a perspective view of a vehicle impact

15 attenuator according to a first embodiment of the present invention. Fig. 2 (a) to (d) are longitudinal sectional views illustrating the deformation of the vehicle impact attenuator of Fig. 1 at the time of a vehicle collision.

As illustrated in Fig. 1, the vehicle impact

20 attenuator 100 according to the first embodiment of the present invention comprises a shock absorber 10 that deforms upon a collision by a vehicle to thereby mitigate the impact on the vehicle, a support 20 for the shock absorber 10, and a holding portion 30 that is fixed on an

25 installation surface E and holds the support 20 in a

vertical position on the installation surface E. The
holding portion 30 comprises a release portion having a
breaking strength that allows the release portion to
fracture upon application of a load equal to or exceeding
5   a set value and thereby release the support 20. Further,
the support 20 has a deformation strength that allows the
support to plastically deform upon application of a load
less than the set value.

        The holding portion 30 comprises a connecting
10   portion 31 fixed on a lower part of the support 20 so as
to hold the support 20 in a vertical position, and anchor
bolts 33 implanted in the installation surface E through
engaging holes 32 provided in the connecting portion 31.
The anchor bolts 33 correspond to the release portion, and
15   fracture upon application of a load equal to or exceeding
a set value to thereby release the support 20.

        Herein, the "installation surface" E, on which
the vehicle impact attenuator 100 is installed, is a road
surface, the ground near a road, or the upper surface of a
20   base, such as a concrete base, provided on the ground near
a road. Further, "release" means making the support 20
incapable of supporting the shock absorber 10 so that the
buffering action of the shock absorber is no longer
effective, e.g., separating the support 20 from the fixed
25   position on the installation surface E, or collapsing the

support 20. These terms are used with the same meanings throughout the specification and claims.

The shock absorber 10 is preferably formed of a plastic cushioning material, such as expandable

5   polystyrene (EPS), expanded polyethylene, expanded polypropylene, expanded polyurethane, or the like. However, other cushioning materials, such as paper cushioning materials, air cushioning materials, etc., are also usable. Although the shock absorber 10 in this

10 embodiment has a doughnut-like shape with a hollow in the middle for inserting the support 20, the shock absorber 10 may have another shape as long as it can be supported by the support 20 at the time of a vehicle collision.

The support 20 is a pipe-like member (e.g., a

15 cylindrical steel pipe), and the plastic deformation occurs as a flattening of the pipe-like support 20. The pipe-like support 20 is made of iron in this embodiment, but it may be made of another metal, a plastic with high bending strength, or another material capable of

20 effectively absorbing the impact of a vehicle collision by plastic deformation.

Further, in the embodiment, the pipe-like support 20 contains an internal cushioning material 23, and sealed with a lid 22 for protection against rain.

25 Various cushioning materials are usable as the internal

cushioning material 23, including the above-mentioned
plastic cushioning materials, paper cushioning materials,
air cushioning materials, etc. The internal cushioning
material 23 may be varied in shape and size, from a

5   granular or pebble-sized material to a one-piece
cylindrical material to be inserted into the pipe-like
support 20. Alternatively, the internal cushioning
material 23 may be omitted.

        When a vehicle C collides with the vehicle
10   impact attenuator 100 according to the first embodiment of
the present invention thus constructed, the impact is
first absorbed by the deformation of the shock absorber 10
as shown in Fig. 2 (b), then by the plastic deformation of
the support 20 as shown in Fig. 2 (c), and then by the
15   fracture of the holding portion 30. When the load exceeds
the set value, the anchor bolts 33 of the holding portion
30 fracture to release the support 20 as shown in Fig. 2
(d). Therefore, the impact on the vehicle C can be
limited to a predetermined value. It is preferable that,
20   after being released, the shock absorber 10 and support 20
be slid, while retaining an approximately vertical
position, by a guiding means (not shown), such as casters
or guide rails as disclosed in Publications 1 and 2.

        Thus, the vehicle impact attenuator 100 of this
25   embodiment can absorb an impact not only by the buffering

actions of the shock absorber 10 and holding portion 30,
but also by the plastic deformation of the support 20,
therefore achieving an impact load absorbing capacity that
is higher than that achieved by the flexibility of the

5   shock absorber 10 due to the contribution of the plastic
deformation. Because such a structure does not require
that the volume of the vehicle impact attenuator 100 be
increased, the attenuator 100 has a higher impact load
absorbing capacity per installation space than known

10   vehicle impact attenuators. Consequently, the vehicle
impact attenuator 100 can be installed in a narrow
installation place with limited space, immediately stop
the colliding vehicle C, and effectively mitigate the
impact on the vehicle C.

15   In this embodiment, since a pipe-like member,
such as a cylindrical steel pipe, is used as the support
20, the plastic deformation to mitigate the impact occurs
as a dent in the direction of the collision on the support
20 and then a flattening by expansion of the dent in a

20   direction approximately perpendicular to the direction of
the collision. The flattening, in combination with the
bending in the vertical direction, flexibly absorbs the
impact from the direction of the collision.

Moreover, because the flattening does not depend

25   on the direction of the collision, the buffering action is

stabilized. When the shock absorber 10 has a doughnut-
like shape and the support 20 is a cylindrical pipe-like
member as in this embodiment, the whole body of the
attenuator is axially symmetric, and therefore both the

5   shock absorber 10 and support 20 effectively exhibit
buffering actions, regardless of the direction of the
collision of the vehicle C. Further, the use of a
general-purpose product as the pipe-like support 20
reduces the cost.

10   Since this embodiment uses the internal
cushioning material 23, which contributes to the
absorption of the impact at the time of flattening of the
pipe-like support 20, the impact absorbing capacity of the
pipe-like support 20 can be easily optimized by selecting

15   the presence or absence, and the form and quality of the
internal cushioning material 23. This makes it possible
to easily realize the vehicle impact attenuator 100 with
an impact absorbing capacity suitable for the conditions
of the installation site.

20   Moreover, the use of anchor bolts 33 makes it
easy to realize a release portion that fractures upon
application of a load equal to or exceeding a set value to
thereby release the support 20.

          The set value for the fracture of the release

25   portion (anchor bolts 33), the yield point load that

flattens the pipe-like support 20, the quality, outer
diameter and wall thickness of the pipe-like support 20,
the presence or absence and type of the internal
cushioning material 23 can be optimally selected according
5   to the conditions of the installation site.

On ordinary installation sites, i.e., road
surfaces or roadsides, the weight of a colliding vehicle
can be assumed to be 0.5 to 3 t, and the acceleration
generated by the collision to be 100 to 300 m/s^2. In this
10   case, it is preferable that, with respect to the support
20, the set value for the fracture of the release portion
(anchor bolts 33) be 50 to 900 kN, and the yield point
load that flattens the pipe-like support 20 be 25 to 800
kN. More preferably, the set value is 80 to 400 kN and
15   the yield point load is 50 to 350 kN, and even more
preferably, the set value is 120 to 250 kN, and the yield
point load is 100 to 200 kN. By adjusting the set value
and yield point load within the above ranges, the above-
mentioned effects can be accomplished to a remarkable
20   extent.

The pipe-like support 20 is preferably made of
iron or plastic and preferably has an outer diameter of
100 to 800 mm and a wall thickness of 0.8 to 100 mm. More
preferably, the outer diameter is 130 to 500 mm and the
25   wall thickness is 1.0 to 20 mm, and even more preferably,

the outer diameter is 200 to 320 mm and the wall thickness
is 1.6 to 6 mm. This makes it possible to adjust the
yield point load of the pipe-like support 20 within the
above range.

5   In particular, when using a plastic, such as a
glass fiber reinforced phenolic resin or like plastic with
high bending strength, the pipe-like support 20 preferably
has an outer diameter of 100 to 800 mm and a wall
thickness of 1.6 to 100 mm, more preferably an outer
10   diameter of 130 to 400 mm and a wall thickness of 1.6 to
40 mm, and even more preferably an outer diameter of 200
to 350 mm and a wall thickness of 3 to 12 mm.
(Second embodiment)

          Fig. 3 is a perspective view of a vehicle impact
15   attenuator according to a second embodiment of the present
invention. Fig. 4 is a series of longitudinal sectional
views illustrating the deformation of the vehicle impact
attenuator illustrated in Fig. 3 at the time of a vehicle
collision.

20   As shown in the figures, the vehicle impact
attenuator 100A according to the second embodiment of the
present invention comprises a shock absorber 10A that
deforms upon a collision by a vehicle to thereby mitigate
the impact on the vehicle, and a support 20A for the shock
25   absorber 10A. Like in the first embodiment, the support

20A is a pipe-like member (e.g., a cylindrical steel pipe).
A continuing portion 32A formed as a lower part of the
support 20A is buried in a region below the installation
surface E (hereafter the installation surface E and the

5   region below it are collectively referred to as the
"installation area"), whereby the support 20A is held
vertically to the installation surface E. The support 20A
has cuts 31A in a part that is slightly above the
installation surface E. The cuts 31A penetrate the

10   support 20A, and have elongated openings along a plane
approximately perpendicular to the major axis of the
support 20A. The continuing portion 32 and burying hole
formed in the installation area constitute the holding
portion 30A.

15   The cuts 31A of the support 20A form a release
portion that serves as starting points for a fracture due
to a load equal to or exceeding a set value. Namely, the
breaking strength of parts adjacent to the cuts 31A of the
support 20A is set so that the parts are fractured by a

20   load equal to or exceeding a set value to thereby release
the support 20A. However, the support 20A is not designed
to plastically deform as in the first embodiment.
Specifically, the set value for the fracture of the parts
adjacent to the cuts 31A is lower than the yield point

25   load that flattens the pipe-like support 20A.

The shock absorber 10A is the same as the shock absorber in the first embodiment and thus the explanation thereof is omitted.

When a vehicle C collides with the vehicle
5   impact attenuator 100A of this embodiment thus constructed, the shock absorber 10A deforms to absorb the impact as illustrated in Fig. 4 (b). When the load equals to or exceeds the set value, the cuts 31A serve as starting points to fracture the parts adjacent thereto, thereby
10   releasing the support 20A. Accordingly, the impact on the vehicle C can be limited to a predetermined value.

The vehicle impact attenuator 100A of this embodiment has a simple structure comprising a plain one-piece pipe-like member as the support 20A, the pipe-like
15   member having cuts 31A in its lower part. Such a structure enables manufacturing the vehicle impact attenuator 100A by a small number of steps and at low cost.

Further, the support 20A can be installed by burying its lower part (the continuing portion 32A) in a
20   burying hole provided in the installation area, in such a manner that the cuts 31A are disposed above the installation surface E. This simplifies and facilitates the installation, reduces the installation cost, and decreases the necessary installation space.

25   (Third embodiment)

Fig. 5 is a perspective view illustrating a vehicle impact attenuator according to a third embodiment of the present invention. Fig. 6 is a series of longitudinal sectional views illustrating the deformation

5   of the vehicle impact attenuator illustrated in Fig. 5 at the time of a vehicle collision.

As shown in the figures, the vehicle impact attenuator 100B according to the third embodiment of the present invention comprises a shock absorber 10B that

10 deforms upon a collision by a vehicle to thereby mitigate the impact on the vehicle, a support 20B for the shock absorber 10B, and a holding portion 30B that is fixed on an installation surface E to hold the support 20B vertically to the installation surface E. The holding

15 portion 30B comprises a continuing portion 32B formed as a lower part of the support 20B, and a fitting member 34B buried below the installation surface E to engage and hold the continuing portion 32B, whereby the support 20B is held in a vertical position. Like in the second

20 embodiment, the support 20B has, as a release portion, in a part slightly above the installation surface E, cuts 31B with elongated openings that serve as starting points for a fracture due to a load equal to or exceeding a set value. Namely, the breaking strength of parts adjacent to the

25 cuts 31B of the support 20B is set so that the region is

fractured by a load equal to or exceeding the set value to thereby release the support 20B. Furthermore, like in the first embodiment, the deformation strength of the support 20B is established so as to allow the support 20B to

5   plastically deform upon application of a load less than the set value.

The shock absorber 10B is the same as the shock absorber in the first embodiment, and thus the explanation thereof is omitted.

10   Like in the first embodiment, the support 20B is a pipe-like member (e.g., a cylindrical steel pipe), and the plastic deformation occurs as a flattening of the pipe-like support 20B.

Further, in this embodiment, the fitting member

15   34B is sufficiently strong to approximately retain its original shape even after the support 20B fractures at the parts adjacent to the cuts 31B. Such a fitting member 34B preferably has a yield point load of 80 to 1500 kN. When the fitting member 34B has a cylindrical shape that is

20   capable of accommodating the continuing portion 32B as in this embodiment, it is preferable that the fitting member 34B be made of metal, such as iron, and have an inner diameter slightly larger than the outer diameter of the continuing portion 32B, with a clearance of 0 to 30 mm,

25   and a wall thickness of 3 to 80 mm.

When a vehicle C collides with the vehicle impact attenuator 100B according to the third embodiment of the present invention thus constructed, the impact is first absorbed by the deformation of the shock absorber

5   10B as shown in Fig. 6 (b), then by the plastic deformation of the support 20B as shown in Fig. 6 (c), and then by the fracture of the parts adjacent to the cuts 31B.   When a load equals to or exceeding the set value is applied, the cuts 31B serve as starting points for the

10 fracture of the parts adjacent to the cuts 31B to thereby release the support 20B.   Therefore, the impact on the vehicle C can be limited to a predetermined value.

Thus, the vehicle impact attenuator 100B according to this embodiment, like the attenuator of the

15 first embodiment, has a high impact load absorbing capacity because of the contribution of the plastic deformation of the support 20B, increasing the impact load absorbing capacity per installation space.

Further, like in the second embodiment, the

20 vehicle impact attenuator 100B of this embodiment has a simple structure comprising a plain one-piece pipe-like member as the support 20B, the pipe-like member having cuts 31B in its lower part, and therefore can be produced and installed at low cost. Furthermore, the attenuator

25 can be installed in a narrow place with limited space,

immediately stop a colliding vehicle C, and mitigate the
impact on the vehicle C.

Moreover, since the attenuator of this
embodiment comprises a fitting member 34B, even when a
5   load equal to or exceeding the set value is applied at the
time of a vehicle collision, the impact is concentrated in
the region with the cuts 31B, which is less strong than
the fitting member 34B. This allows the region with the
cuts 31B to smoothly fracture and effectively prevents
10   damage to the fitting member 34B.

After a collision, the base portion (fitting
member 34B) of the vehicle impact attenuator 100B can be
made usable by simply removing the remains (the continuing
portion 32B that forms a lower part of the support 20B and
15   other portions) inside or around the fitting member 34B.
Thus, the attenuator can be withdrawn and renewed very
easily, reducing the cost and time necessary for
installation and restoration.

In the first to third embodiments described
20   above, the supports 20, 20A and 20B are pipe-like (e.g.,
cylindrical) members, but the support may have any of
various shapes other than a pipe-like shape. For example,
the support may be a rod-like member with an H-, U- or S-
shaped cross section as shown in Fig. 7 (a) to (c). It is
25   preferable, however, that the support be a pipe-like

member capable of being held by the holding portion 30,

30A or 30B in a vertical position to support the shock

absorber 10, 10A or 10B, which generally receives an

impact in an approximately horizontal direction.

5   In the second and third embodiments, cuts 31A or

31B are formed in the support 20A or 20B at a part

slightly higher than the installation surface E, in the

shape of elongated through-holes that penetrate the

support 20A or 20B and are disposed along a plane

10   approximately perpendicular to the major axis of the

support 20A or 20B. However, the cuts 31A and 31B may

have other shapes, and need not be through-holes.

           For example, cuts with various shapes as shown

in Fig. 8 (a) to (c) may be provided to the continuing

15   portion. In Fig. 8 (a) and (b), a plurality of circular

or elongated rectangular holes are provided approximately

in a line along an approximately circumferential direction.

In Fig. 8 (c), a plurality of circular holes are disposed

so as to form a plurality of lines.

20   As shown in Fig. 8 (d) (a partial longitudinal

sectional view of the support), the support may be

provided with a cut (or a notch) that does not penetrate

the support and is formed along a plane approximately

perpendicular to the major axis of the support. Such a

25   cut may be formed on a solid member as well as a hollow

member such as a pipe.

Since the yield point load of the parts adjacent
to the cuts in the support varies with the shape and other
features of the cuts, the breaking strength of the parts
5   adjacent to the cuts can be easily adjusted to a desired
value by designing the cuts (size, shape, number,
arrangement) according to the wall thickness and strength
of the support. Therefore, a vehicle impact attenuator
can be easily realized which has a breaking strength
10   suitable for the conditions of the installation site.

Further, the form of the cuts can be selected
depending on whether a single attenuator or a set of two
or more attenuators is used. When using a single vehicle
impact attenuator, it is preferable that, at the time of
15   the fracture of the region with cuts, the support be
pulled downward with the bottom of the support still
fastened to the installation surface to some degree, in
order to stop the support from scattering and thus prevent
secondary accidents. For that purpose, the continuing
20   portion is preferably provided with a fastening portion
311 on a part of its periphery as shown in Fig. 8 (b). By
installing the vehicle impact attenuator so that the
fastening portion 311 is positioned on the back side of
the support as seen from the colliding vehicle, the
25   support remains fastened to the installation surface to

some degree by the fastening portion on its back side,
even when the region with cuts is fractured due to a
collision.

When using a set of two or more vehicle impact

5   attenuators, the attenuator installed in the front part of
the set is preferably made so that the support, at the
time of the fracture of the region with cuts, be separated
from the installation surface and slide while retaining an
approximately vertical position. Holes that facilitate

10   separation of the support can be easily realized by
increasing the area occupied by the cuts (e.g., increasing
the number of the cuts or enlarging the openings of the
cuts), by reducing the spaces between adjacent cuts, or by
increasing the depth of the notch shown in Fig. 8 (d).

15   This makes it possible to continuously retain, after the
fracture of the region with cuts, the impact absorbing
effect of the shock absorber and the support of the
subsequent vehicle impact attenuator. Preferably,
scattering of the support is prevented by a suitable

20   guiding means, rope or the like. In the vehicle impact
attenuator installed in the back part of the set, the
support is preferably pulled downward while the bottom of
the support remains fastened to the installation surface.

In the third embodiment, a cylindrical fitting

25   member is used, but the fitting member may have any shape

as long as it fits on the continuing portion to hold the
support in a vertical position and approximately retain
original shape after the fracture of the release portion
(cuts).

5   Fig. 9 (a) and (b) are longitudinal sectional
views illustrating other examples of the fitting member
and continuing portion.

          The fitting member 34C shown in Fig. 9 (a) is a
floorboard-like member to be buried below the installation
10   surface. The upper surface of the floorboard-like member
is provided with insertion openings 341C to which the
continuing portion 32C is inserted, to thereby hold the
support in a vertical position. In the fitting member 34D
shown in Fig. 9 (b), the upper surface of the floorboard-
15   like member is provided with projections each of which is
inserted into the continuing portion 32D, to thereby hold
the support in a vertical position. In the structure
shown in (b), the cuts of the support are formed at a part
slightly higher than the top end of the projections 342D.

20   In the first to third embodiments, the vehicle
impact attenuator is installed singly. However, in places
where a vehicle is likely to collide at a high speed, it
is often suitable to install a plurality of the vehicle
impact attenuators side by side. In such a case, the use
25   of the fitting member 34C or 34D that has two or more

insertion openings 341C or projections 342D eliminates the necessity of determining the distance between the vehicle impact attenuators at the installation site, facilitating the installation operation.

5   Fig. 10 (a) to (c) are plan views illustrating examples of arrangements of a plurality of vehicle impact attenuators according to the first embodiment of the present invention. As shown in the figure, vehicle impact attenuators 100 are installed on an installation surface E

10   at a median strip end D.

In such arrangements, it is preferable that the vehicle impact attenuators 100 be adjoined so that the shock absorbers are in contact with each other, and arranged along the expected direction of the collision,

15   i.e., the traveling direction of vehicles that may collide with the attenuators. This makes it possible for the subsequent vehicle impact attenuator 100 to immediately absorb the impact, and thereby stop the colliding vehicle within a short distance and effectively mitigate the

20   impact on the vehicle, even when the impact applied to one of the vehicle impact attenuators 100 reaches the yield point and releases the support 20.

At a median strip end D as shown in Fig. 10, vehicle impact attenuators need to be installed generally

25   within a narrow width of about 40 to 100 cm, and therefore

it is difficult to install known impact attenuators.
However, the vehicle impact attenuator 100 according to
the first embodiment of the present invention has an
increased impact load absorbing capacity per installation
5   space, and can be installed in a narrow place, such as the
median strip end D, while retaining sufficient ability to
stop vehicles and mitigate impacts. In some cases, the
number of the vehicle impact attenuators 100 to be
installed side by side can be decreased, thus greatly
10   reducing the necessary installation space.

The installation of the vehicle impact
attenuators at a median strip end is explained above, but
the vehicle impact attenuators are also applicable to
various other places where vehicle collisions are liable
15   to occur, such as road forks, the ends of branch points
for tollgates, etc.

Fig. 11 (a) is a perspective view showing a
vehicle impact attenuator according to the third
embodiment of the present invention installed behind an
20   end portion of a guardrail G supported by a plurality of
poles P. Fig. 11 is a plan view of the vehicle impact
attenuator and guardrail. As shown in the figure, the
vehicle impact attenuator 100B is installed on the
installation surface E behind the end portion of the
25   guardrail.

The guardrail G is firmly constructed usually of steel to prevent vehicles from entering the area protected thereby. However, the end portion past the pole P supporting the guardrail G will sharply bend when a

5   vehicle collides with it, and thus cannot sufficiently prevent vehicles from entering, exposing the protected area to danger.

The vehicle impact attenuator 100B can be installed in a narrow installation place with limited

10   space as mentioned above and shown in the figure. The vehicle impact attenuator 100B installed on the installation surface E behind an end portion of a guardrail can immediately stop a colliding vehicle and effectively mitigate the impact on the vehicle.

15   (Fourth embodiment)

Fig. 12 is a perspective view of a vehicle impact attenuator according to a fourth embodiment of the present invention. Fig. 13 (a) and (b) are plan views showing examples of arrangements of a plurality of the

20   vehicle impact attenuator shown in Fig. 12. It can be construed that this vehicle impact attenuator comprises a pipe-like support having a figure-of-8-shaped cross section (see Fig. 7).

As illustrated in Fig. 12, the vehicle impact

25   attenuator 100C according to the fourth embodiment of the

present invention comprises a shock absorber 10C that

deforms upon a collision by a vehicle to thereby mitigate

the impact on the vehicle, two supports 20C for the shock

absorber 10C, and holding portions 30C that are fixed

5   below an installation surface E to hold the two supports

20C vertically to the installation surface E. The

supports 20C and holding portions 30C have the same

structures as the support 20A or 20B and the holding

portion 30A or 30B of the vehicle impact attenuator 100A

10   or 100B according to the second or third embodiment.

Unlike the vehicle impact attenuators 100A and

100B according to the second and third embodiments, the

vehicle impact attenuator 100C comprises two supports 20C

each having cuts 31C and continuing portion 32C, two

15   holding portions 30C, and a shock absorber 10C that is an

approximately elliptical cylinder surrounding the two

pipe-like supports 20C, the shock absorber 10C being in

direct contact with the installation surface E. The

vehicle impact attenuator 100C is the same as the vehicle

20   impact attenuator 100B according to the third embodiment

of the present invention except for the above points.

Thus, the explanation of the vehicle impact attenuator

100C is omitted. With respect to the set value for the

fracture of the cuts 31 and the yield point load that

25   flattens the pipe-like supports 20C, it is preferable that

the total set value and total yield point load of the two

supports 30C be within the ranges specified in the

explanation of the first embodiment.

Like the third embodiment, the vehicle impact

5   attenuator 100C according to this embodiment has an

increased impact load absorbing capacity due to the

contribution of the plastic deformation of the supports

20C, thereby achieving a high impact load absorbing

capacity per installation space. In particular, the

10   vehicle impact attenuator of this embodiment comprises two

adjacent pipe-like supports 20C, whose plastic deformation

greatly contributes to a higher impact load absorbing

capacity. Furthermore, the supports 20C dissipate the

impact on a colliding vehicle.

15   When a plurality of such vehicle impact

attenuators are installed in a row, it is preferable to

dispose two or more vehicle impact attenuators 100C in the

direction perpendicular to the direction of the row of the

two pipe-like supports 20C, as shown in Fig. 13 (a) and

20   (b). Moreover, as mentioned above, the design of the cuts

and the type of internal cushioning material can be

selected to vary the vehicle impact attenuators with

respect to the set value for the fracture of the supports

20C or the yield point load that flattens the supports 20C,

25   according to the order in the row. For example, it is

preferable that, in the vehicle impact attenuator 100C in the front of the row, a plurality of cuts be provided in a line along an approximately circumferential direction as mentioned above, to thereby facilitate the fracture. In

5 the vehicle impact attenuator 100C in the back of the row, it is preferable that the fastening portion mentioned above be provided on a part of the support 20C and allow the support 20C to remain fastened to the installation surface even when the cuts are fractured.

10 (Example 1)

With respect to vehicle impact attenuators according to the first, third or fourth embodiment, which absorb an impact load by the flattening of the pipe-like member, the preferable ranges of the outer diameter and

15 wall thickness of the pipe-like support were studied, assuming that the weight of the colliding vehicle is 1 t, the acceleration generated by the collision is 100 to 300 m/s^2, and the position at which the vehicle struck is 50 cm high from the ground. The outer diameters were

20 selected according to JIS G3444. The pipe-like supports used were made of cast iron and had a breaking stress of 400 MPa. In addition to vehicle impact attenuators comprising one pipe-like member as in the first or third embodiment, vehicle impact attenuators comprising two

25 pipe-like supports as in the fourth embodiment, and

vehicle impact attenuators comprising three pipe-like

supports were used. Table 1 shows the results.

In the table, "bending" and "flattening"

indicate the loads absorbed by the bending and flattening

5   of the pipe-like member, respectively. From the above

assumption, the total of the loads needs to be 100 to 300

kN or more. Further, "I.C.: internal cushioning material"

in the "adjustment" column indicates that the use of an

internal cushioning material in the pipe-like member is

10   preferable.

The pressure-applying end of a pressure device

was pressed to the center of the pipe-like member(s),

which was 50 cm from each of the fixed ends, to measure

the displacement and load of the pressure-applying end.

15   Fig. 14 (a) and (b) are graphs schematically showing the

relationships between the displacement and load of

support(s) containing an internal cushioning material and

support(s) without an internal cushioning material,

respectively. Fig. 14 (b) reveals that the use of an

20   internal cushioning material achieved the impact load

absorbing capacity indicated by Curve F2, which is greater

than the impact load absorbing capacity indicated by Curve

F1, by the amount shown by Area R.

Table 1

Outer diameter	Number of supports	Thickness	Bending	Flattening	Adjustment
216.3 mm	1	3.5 mm	100 kN	20 kN	I.C.
		7.5 mm	200 kN	95 kN	I.C.
		12 mm	300 kN	250 kN	Unnecessary
	2	1.7 mm	50 kN	4.5 kN	I.C.
		3.5 mm	100 kN	20 kN	I.C.
		6.0 mm	150 kN	60 kN	I.C.
318.5 mm	1	1.6 mm	100 kN	2.7 kN	I.C.
		3.2 mm	200 kN	11 kN	I.C.
		5 mm	300 kN	27 kN	I.C.
	2	0.8 mm	50 kN	0.7 kN	Impossible
		1.6 mm	100 kN	2.7 kN	I.C.
		2.4 mm	150 kN	6 kN	I.C.
139.8 mm	2	4.5 mm	50 kN	52 kN	Unnecessary
		10 mm	100 kN	270 kN	S.A.
		20 mm	200 kN	1000 kN	S.A.
	3	2.9 mm	33 kN	21 kN	I.C.
		6.2 mm	66 kN	100 kN	S.A.
		10 mm	100 kN	270 kN	S.A.
114.3 mm	2	4.5 mm			
		7.5 mm	50 kN	200 kN	S.A.
		20 mm	100 kN	1700 kN	S.A.
		(Solid)	200 kN	None	S.A.
	3	2.9 mm			
		4.5 mm	33 kN	65 kN	S.A.
		10 mm	66 kN	350 kN	S.A.
		20 mm	100 kN	1700 kN	S.A.

I.C.: Internal cushioning material

S.A.: Shock absorber

As shown in Table 1, when the outer diameter is 216.3 mm, pipe-like supports with the three thicknesses, i.e., 3.5 mm, 7.5 mm and 12 mm, as used singly, achieve a total load of 100 to 300 kN or more. The support with a

5   thickness of 3.5 mm or 7.5 mm can be made capable of withstanding a load of 300 kN or more by adjustment using an internal cushioning material. Therefore, in the case of using support(s) with an outer diameter of 216.3 mm, a thickness of 3.5 to 12 mm at least is applicable. The

10   table also reveals that, when using two pipe-like supports with an outer diameter of 216.3 mm, a thickness of 1.7 to 6 mm at least is applicable.

The table also shows the following: when the outer diameter is 318.5 mm, a thickness of 1.6 to 5 mm at

15   least is applicable in the case of using one pipe-like support, and a thickness of 1.6 to 2.4 mm at least is applicable in the case of using two pipe-like supports; when the outer diameter is 139.8 mm, a thickness of 4.5 to 20 mm at least is applicable in the case of using two

20   pipe-like supports, and a thickness of 2.9 to 10 mm at least is applicable in the case of using three pipe-like supports; and when the outer diameter is 114.3 mm, a thickness of 4.5 to 20 mm at least is applicable in the case of using two pipe-like members, and a thickness of

25   2.9 to 10 mm at least is applicable in the case of using

three pipe-like members.

In Table 1, "S.A. :shock absorber" means that the load that can be withstood was adjusted by disposing a plurality of vehicle impact attenuators as a set. The vehicle impact attenuators installed mainly in the front of such a set are preferably provided with cuts that facilitate separation, as mentioned above. For example, 72 circular through-holes with a diameter of 5 mm can be formed in a row along the circumferential direction of a pipe-like support with an outer diameter of 216.3 mm. Such holes give a void ratio (hole diameter x hole number/support circumference) of about 50% and thereby facilitate separation at the time of fracture. In a vehicle impact attenuator whose support is preferably separated at the time of fracture, it is desirable that the void ratio of the pipe-like support be 40 to 90%.
(Fifth embodiment)

Fig. 15 is a perspective view of a vehicle impact attenuator according to a fifth embodiment of the present invention. Like the vehicle impact attenuator 100B shown in Fig. 5, this vehicle impact attenuator 100E comprises a shock absorber 10E, a support 20E, a holding portion 30E and cuts 31E, and further comprises a helical coil 50 inside the support 20E. Like in the vehicle impact attenuator 100B shown in Fig. 5, the support 20E

has deformation strength that allows the support to be

plastically deformed by a load less than a set value, and

the cuts 31E have a breaking strength such that they serve

as fracture starting points when receiving a load equal to

5   or exceeding a predetermined value, to thereby release the

support 20E.

The coil 50 is a circular coil comprising

approximately concentric circular turns (windings). The

coil 50 is made of metal, such as iron, which is not

10   elastic and is plastically deformable by a load equal to

or exceeding a predetermined value. Examples of usable

materials of the coil 50 include mild steel, such as

structural steel.

The coil 50 has a hook on each end. The support

15   20E has first and second fixing members 51, 52 in its

interior, the fixing members 51, 52 being disposed above

and below the cuts 31E and having an opening. The hooks

of the coil 50 are each hooked to the opening of the first

and second fixing members 51, 52.

20   Fig. 16 shows the deformation of the vehicle

impact attenuator 100E according to this embodiment thus

constructed, at the time of a collision with a vehicle C.

When the vehicle C collides, the vehicle impact attenuator

100E, originally in the state shown in Fig. 16 (a), first

25   absorbs the impact by the deformation of the shock

absorber 10E and the plastic deformation of the support

20E, as shown in (b). Subsequently, the impact is

absorbed while the support 20E is fractured into two

pieces, with the cuts 31E serving as fracture starting

5   points, as shown in (c). Further, if the vehicle C

retains kinetic energy even after the upper part of the

support 20E has been completely separated from the lower

part, the kinetic energy of the vehicle is absorbed while

the upper part of support 20E is moved by the vehicle C,

10   namely, during the plastic deformation of the coil 50 by

the force applied by the vehicle C.

        The vehicle impact attenuator 100E according to

this embodiment is preferable, since the impact is

absorbed approximately continuously during the impact

15   absorbing process by the coil 50 shown in (d), unlike

other embodiments. Fig. 17 is a graph schematically

showing, like Fig. 14, the relation between the

displacement and load of the pressure-applying end, with

respect to the vehicle impact attenuator according to this

20   embodiment. In Fig. 17, F3 indicates that, after an

impact absorption similar to that indicated in Fig. 14 is

complete, the impact is continuously absorbed by the coil.

In Fig. 17, the curve continues to the right as long as

the coil 50 can extend.

25   A spring with high elasticity, such as an

ordinary steel spring, can absorb vehicle impact energy

continuously, but exhibits a large restoring force after

the deformation and may cause a secondary accident. In

contrast, the coil 50 in this embodiment is made of a

5   material that has low elasticity and requires a load equal

to or exceeding a predetermined value for plastic

deformation, and therefore has a very small restoring

force and is very unlikely to cause a secondary accident.

In the above explanation, the coil 50 is a

10   circular coil, but it is not limited thereto as long as it

is a wire-like member that is made of a plastically

deformable material, requires a load equal to or exceeding

a predetermined value for extension, and is placed inside

the support 20E. For example, each turn of the coil 50

15   may be of any shape, including an oval, an equilateral or

inequilateral polygon, etc.; the turns may vary in size;

or the coil may be a folded wire-like member.

The means and positions to attach the ends of

the coil 50 to the support 20E are not limited, as long as

20   the ends of the coil 50 are positioned above and below the

cuts 31E and attached to the support 20E. For example,

the body of the coil 50 may be placed in the support 20E

and below the holes 31E. In such a case, the space in the

support 20E and above the holes 31E may be filled with a

25   cushioning material. The coil 50 may also be attached

outside the support 20E. In such a case, the vehicle impact attenuator 100E is preferably installed in such a manner that the coil 50 is positioned in the back of the support 20E as seen from the expected colliding vehicle.

5   While a detailed explanation of embodiments of the present invention has been given, the present invention is not limited to the first to fifth embodiments, and various additions and modifications can be made thereto. For example, reflective stickers, lights or the

10   like (not shown), which can prevent vehicle collisions by visual effects, may be installed together with the vehicle impact attenuator.

(Example 2)

        Fig. 18 is a pair of graphs showing the results

15   of an experiment on the coil 50 for use in the vehicle impact attenuator 100E of the fifth embodiment. The coil used in the experiment is made of structural steel, comprises turns with a coil diameter D of about 62 mm, and has a wire diameter d of about 12 mm and a number of turns

20   Na of 3.

        Fig. 18 (a) shows the results of deforming the coil by continuously applying a force to its ends at a deformation rate of about 200 mm/min until the coil is fractured. In graph (a), the load is plotted as ordinate

25   against the deformation as abscissa. The graph shows that

the load was substantially stabilized in the range of 5 kN to 10kN, demonstrating that the energy was efficiently absorbed.

According to JIS B 2704,

$$\tau_0 = 8DP/(\pi d^3) \quad \ldots \text{(Equation 1)}$$

$$\tau = \kappa \tau_0 \quad \ldots \text{(Equation 2)}$$

wherein τ_0 is a torsional stress, τ is a torsion correction stress, P is a load and κ is a stress correction factor.

From Equations 1 and 2,

$$P = (\pi d^3 \tau)/(8D\kappa) \quad \ldots \text{(Equation 3)}$$

wherein $\kappa = (4c-1)/(4c-4) + 0.615/c$, and $c = D/d$.

The experimental results shown in (a) are substituted in Equation 3 to find the range of τ in which the load is stabilized. Since $c = 5.17$ and $\kappa = 1.3$, when P=5 (kN), $\tau = (8D\kappa P)/(\pi d^3) = 594$ (N/mm^2); and when P=10 (kN), $\tau = (8D\kappa P)/(\pi d^3) = 1180$ (N/mm^2). Therefore, the energy can be efficiently absorbed when τ is 60.5 to 121 (N/mm^2).

Further, since an acceleration of about 30 to 150 m/s^2 is generated at the time of a collision of a 1-ton vehicle, a vehicle impact attenuator with ideal strength to absorb energy can be realized by determining a coil diameter D and wire diameter d of the coil that yield an impact load P of about 30 kN to 150 kN by reverse calculation. For example, when using structural steel for

the coil, a coil diameter D of 110 to 130 (mm) and a wire

diameter d of 30 to 40 (mm) yield an impact load P of

about 40 kN to 80 kN.

In addition to these conditions, when the number

5   of turns Na is three or more, the distance required to

absorb the energy of the vehicle, i.e., the distance

required for the coil to be substantially fully extended,

is about 1 m or more, which is practical. Further, when

the number of turns Na is 20 or less, the coil can be

10   placed in the support with a practical height of about 600

mm.

Fig. 18 (b) shows the results of an experiment

on deformation of a coil of the same size and material as

in the above experiment (graph (a)) by applying a force at

15   the same deformation rate as in the above experiment,

except that the load was released four times (at points P1

to P4) during deformation before fracture. The scale of

the ordinate of graph (b) is enlarged as compared with

that of graph (a). In graph (b), the load is decreased to

20   0 at points P1 to P4, and the coil is restored only about

20 mm at each time. This suggests that when a coil is

made of a material that has low elasticity and requires a

load equal to or exceeding a predetermined value for

plastic deformation (e.g., mild steel, including

25   structural steel), the coil can continuously absorb energy

due to its plasticity, and exhibits an extremely small restoring force, therefore making it very unlikely to cause a secondary accident.

5

INDUSTRIAL APPLICABILITY

The present invention provides a vehicle impact attenuator that can be installed at low cost, immediately stop a colliding vehicle, and effectively mitigate the impact on the vehicle.

10